

WHAT IS CLAIMED IS:

1. A rising and moving apparatus, comprising
a wing portion elastically deformed by force exerted by surrounding
fluid, to an extent that allows a body to hover and move;
a driving unit driving the wing portion; and
5 a control unit controlling the manner of driving by the driving unit.
2. The rising and moving apparatus according to claim 1, wherein
said wing portion has torsional rigidity or flexural rigidity of an
upstream side of the fluid higher than the torsional rigidity or flexural
rigidity of the downstream side of the fluid.
3. The rising and moving apparatus according to claim 1, wherein
said wing portion has torsional rigidity or flexural rigidity on the
side of a leading edge higher than the torsional rigidity or flexural rigidity
on the side of a trailing edge.
4. The rising and moving apparatus according to claim 1, wherein
a wave plate structure having ridge lines or valley lines extending
along span direction of the wing is provided at an upstream side of the fluid
at the wing.
5. The rising and moving apparatus according to claim 1, wherein
a wave plate structure having ridge lines or valley lines extending
along span direction of the wing is provided at a leading edge portion of the
wing.
6. The rising and moving apparatus according to claim 1, wherein
thickness of said wing portion on the upstream side of the fluid is
larger than the thickness on the downstream side of the fluid, or a
supporting structure of the wing portion at the upstream side of the fluid is
5 thicker than the support structure at the downstream side of the fluid.

7. The rising and moving apparatus according to claim 1, wherein thickness of said wing portion on the side of a leading edge is larger than the thickness on the side of a trailing edge, or a support structure of said wing portion on the side of the leading edge is thicker than the support structure on the side of the trailing edge.

8. The rising and moving apparatus according to claim 1, wherein angle of attack of said wing portion where fluid velocity is relatively high is smaller than the angle of attack of said wing portion where the fluid velocity is relatively low.

9. The rising and moving apparatus according to claim 1, wherein angle of attack of said wing portion at a tip end is smaller than the angle of attack of said wing portion at a root.

10. The rising and moving apparatus according to claim 1, wherein said wing portion is rotatable about a prescribed center of rotation, and flexural rigidity of a portion relatively closer to the center of rotation is higher than flexural rigidity of a portion relatively far from the center of rotation.

11. The rising and moving apparatus according to claim 1, wherein thickness of said wing at a portion closer to said center of rotation is larger than the thickness far from said center of rotation, or a support structure closer to said center of rotation is thicker than the support structure far from said center of rotation.

12. The rising and moving apparatus according to claim 1, wherein said wing portion is rotatable about a prescribed center of rotation, and torsional rigidity of a portion relatively closer to the center of rotation is higher than the torsional rigidity of a portion relatively far from the center of rotation.

13. The rising and moving apparatus according to claim 1, wherein said wing portion is provided such that the axis of rotation along span direction of the wing is positioned approximately in the middle between the leading edge and the trailing edge of the wing portion.

14. The rising and moving apparatus according to claim 1, wherein during a stroke reversal of said wing, said control unit controls said driving unit such that lower surface of said wing comes into contact with an upper portion of a vortex generated by the flapping motion of said wing
5 portion immediately before the stroke reversal.

15. The rising and moving apparatus according to claim 1, wherein during a stroke reversal of said wing, said control unit controls said driving unit such that elastic deformation occurs so that direction of extension of an axis of rotation of a vortex generated by the stroke reversal
5 matches direction of extension of an axis connecting centers of radii of curvature of said wing portion.

16. The rising and moving apparatus according to claim 1, wherein when said wing portion is driven by said driving unit, a root portion moves periodically, and said wing portion elastically deforms such that said wing has a portion having a different phase of periodic motion than the
5 phase of the periodic motion at the root portion.

17. The rising and moving apparatus according to claim 16, wherein
said wing portion elastically deforms such that a phase of a portion where a relatively large fluid force is exerted is delayed from a phase of a
5 portion where a relatively small fluid force is exerted.

18. The rising and moving apparatus according to claim 17, wherein
said delay in phase is at most 1/2 of one period of said flapping

motion.

19. The rising and moving apparatus according to claim 16,
wherein

said wing portion elastically deforms such that a phase of a tip end
portion is delayed from a phase of a root portion.

20. The rising and moving apparatus according to claim 19,
wherein

said delay in phase is at most 1/2 of one period of said flapping
motion.

21. The rising and moving apparatus according to claim 1, wherein
a manner of control of said control unit controlling said driving unit
and a manner of elastic deformation of said wing are related such that a
prescribed parameter related to flapping rise and movement has the
5 optimal value in accordance with a result of fluid-structure interactive
analysis.

22. The rising and moving apparatus according to claim 21,
wherein

the prescribed parameter related to flapping rise and movement may
be lift force generated by the flapping motion of said wing portion.

23. The rising and moving apparatus according to claim 21,
wherein

the prescribed parameter related to flapping rise and movement is a
value obtained by dividing lift force generated by the flapping motion of
5 said wing portion by a torque necessary for driving said wing portion to
generate the lift force.

24. The rising and moving apparatus according to claim 21,
wherein

the prescribed parameter related to the flapping rise and movement is the highest frequency of said driving unit necessary for realizing said flapping motion of said wing portion.

25. The rising and moving apparatus according to claim 21, wherein

the prescribed parameter related to the flapping rise and movement is a value obtained by dividing the lift force generated by the flapping motion of said wing portion by an energy necessary for generating the lift force.

26. The rising and moving apparatus according to claim 1, wherein said wing portion satisfies the following relation, where f denotes flapping frequency, L denotes representative length, r denotes a distance from a portion having the highest stiffness, w denotes a load on a portion at a distance r from the portion having the highest stiffness, and d denotes a displacement generated at the portion that bears the load w exerted by the load w :

$$0.36 \times 10^{-8} < r^3 \times w/d/(L \times f)^2 < 4.48 \times 10^{-8}.$$

27. The rising and moving apparatus according to claim 1, wherein said wing portion has Young's modulus of 1.77×10^8 to 5.66×10^9 .

28. The rising and moving apparatus according to claim 1, wherein said wing portion has Young's modulus of 2.5×10^8 to 2.0×10^9 .

29. The rising and moving apparatus according to claim 1, wherein said wing portion has Young's modulus of 1.77×10^8 to 2.0×10^9 .

30. The rising and moving apparatus according to claim 1, wherein stiffness of a prescribed portion of said wing portion gradually increases from a tip end portion of said wing portion to a root portion of said wing portion, in proportion to a square of a distance from the tip end

5 portion of said wing portion to said prescribed portion.

31. A method of manufacturing a rising and moving apparatus, comprising:

measuring step of measuring physical values related to an actual structure of a wing of an insect;

5 numerical value giving step of giving numerical values to the physical values related to the structure;

structural model preparing step of preparing an equivalent numerical model of wing structure that can be regarded as equivalent to said actual wing, using said physical value related to the structure given in
10 numerical values;

model varying step of preparing numerical models of a plurality of different types of wing structures in which stiffness parameter of the equivalent numerical model of wing structure is varied;

15 motion measuring step of measuring physical amounts related to manner of flapping motion while the actual wing of the insect is caused to perform flapping motion;

motion model preparing step of preparing a numerical model of flapping motion in which the physical values related to the manner of flapping motion are expressed as numerical values;

20 motion step of causing a plurality of different types of numerical models of wing structures to perform flapping motion represented by the numerical model of flapping motion, respectively, in a preset virtual fluid for analysis;

25 analyzing step of calculating, in said motion step, a numerical model related to the fluid of the virtual fluid and the numerical model related to the structure of the numerical model of wing structure, respectively; wherein

30 in said analyzing step, fluid-structure interactive analysis is used in which behavior of the fluid and behavior of the structure including interaction therebetween are analyzed; said method further comprising wing portion manufacturing step of manufacturing a wing portion

that is driven by a driving apparatus, using said plurality of different types of numerical models of wing structures obtained through said analyzing step; wherein

35 in said wing portion manufacturing step,
 a prescribed parameter of the numerical model related to the fluid of said virtual fluid and the numerical model of the structure of said numerical model of wing structure is extracted, and
40 said wing portion is manufactured using a numerical model of wing structure in which said prescribed parameter has an optimal value.

32. The method of manufacturing a rising and moving apparatus according to claim 31, wherein

 said prescribed parameter is lift force generated at said numerical model of wing structure when said numerical model of wing structure is
5 caused to perform said flapping motion.

33. The method of manufacturing a rising and moving apparatus according to claim 31, wherein

 said prescribed parameter is a value obtained by dividing lift force generated at the numerical model of wing structure when said numerical
5 model of wing structure is caused to perform the flapping motion, by a torque necessary for driving said numerical model of wing structure to generate the lift force.

34. The method of manufacturing a rising and moving apparatus according to claim 31, wherein

 said prescribed parameter is maximum frequency of said driving unit necessary to cause said numerical model of wing structure to perform said
5 flapping motion.

35. The method of manufacturing a rising and moving apparatus according to claim 31, wherein

 said prescribed parameter is a value obtained by dividing lift force

- 5 generated at the numerical model of wing structure when said numerical model of wing structure is caused to perform the flapping motion, by an energy necessary for generating the lift force.